Journal of Forestry Research (2011) 22(2): 167−174
DOI 10.1007/s11676-011-0145-0

ORIGINAL PAPER

National assessment of the evolution of forest fragmentation in Mexico

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Received: 2010-08-03; Accepted: 2010-09-27

Abstract: This paper presents assessments of the fragmentation of the temperate and tropical forests in Mexico at the national level for two dates 1993 and 2002. The study was based on land use and vegetation cover data sets scale 1:250,000. Two broad forest types (Temperate Forests and Tropical Forests) and five more specific forest types (Broadleaf Forests, and Coniferous Forests; Tropical Dry Deciduous Forests, Tropical Sub-evergreen Forests, and Tropical Evergreen Forests) were defined to conduct the analyses. FragStats 3.3 was used to estimate nine metrics of the spatial pattern of the forests for each forest type and date considered. The results indicate that the land cover transitions that have occurred between 1993 and 2002 have resulted in more isolated forest patches with simpler shapes in both the Temperate and Tropical Forests. The remaining Tropical Forest patches have become smaller and more numerous. In contrast, the remaining Temperate Forest patches are fewer and on average larger. Of the more specific forest types defined in this study, the Broadleaf Forests have the highest indicators of fragmentation. However these forests are usually embedded or adjacent to Coniferous Forests. Of more concern for conservation purposes are the high values of fragmentation metrics found for the Tropical Evergreen Forests and Tropical Dry Deciduous Forests, because these forest types are usually surrounded by non-forest land covers or anthropogenic land uses.

Keywords: forest fragmentation; Mexico; FragStats.

The online version is available at http://www.springerlink.com

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Responsible editor: Chai Ruihai

Introduction

Human activities and natural processes have significantly changed the characteristics of the Earth's forest ecosystems (Turner et al. 1990; Meyer & Turner 1994; Matthews et al. 2000; Riitters et al. 2000; Wade et al. 2003; Foley et al. 2005; Siry et al. 2005). These changes are threatening the sustainability of these ecosystems (World Resources Institute 2000) and are affecting their capacity to provide diverse goods and services such as climate regulation (Laurance 2000; Semazzi and Yi 2001; Zhang et al. 2001; Laurance and Williamson 2002), biodiversity (Sala et al. 2000; Jenkins 2003), water yields (Farley et al. 2005) and carbon sequestration (Winjum et al. 1992; Chambers et al. 2001) among others.

Historically, emphasis has been made on estimating the extent of the remaining temperate and tropical forests at the national and global levels (e.g. Matthews 2001; Achard et al. 2002; Food and Agriculture Organization of the United Nations FAO Global Forest Resources Assessments http://www.fao.org/forestry/1191/en/; Montreal Process country reports http://www.rinya.maff.go.jp/mpci/). Although total remaining area and deforestation rates are important parameters for estimating the sustainability of forest ecosystems, equally important are the conditions of the remaining forests with regard to their ownership, composition, structure, and spatial pattern. Among these factors, spatial pattern (estimated through different measures of fragmentation) is of particular importance in estimating the capacity of the remaining forests to sustain critical ecosystem components and functions at different temporal and spatial scales (Lindenmayer et al. 2002; McAlpine & Eyre 2002; Garcia-Rigoro & Saura 2005; Kupfer 2006). Hence, there is a growing interest in studying the fragmentation of forest ecosystems at broad spatial scales to support the sustainable use of temperate and tropical forests (Kupfer 2006).

In Mexico there have been numerous studies of the fragmentation of the forests (approximately 41 in the last 10 years). However, these studies have not used a standard methodology making comparisons and integration of their results difficult. Also, these

studies have been limited to specific types of forests or to the effects of fragmentation on specific flora or fauna species at the local and regional levels. To this date there has not been a consistent national-level evaluation of the fragmentation of the temperate and tropical forests in Mexico, nor an assessment of the changes on this parameter through time. This paper presents fills this gap by estimating several fragmentation metrics for two dates (1993 and 2002) at the national level for all the forest covers existing in the country.

The remainder of the paper is organized as follows: Section two presents a brief background on forest fragmentation and the efforts that have been carried out in Mexico to estimate it; section three presents the details of the methodology used in this study; section four presents and discusses the results of the fragmentation metrics considered in the study; and finally, section six draws general and specific conclusions from this study.

Forest fragmentation background

The issue of forest, and more generally habitat, fragmentation is complex and has been studied extensively (Fazey et al. 2005; Lindenmayer & Fisher 2006). There are numerous publications on the efforts to define it and on the theoretical approaches that have been taken to understand it (e.g. Harrison & Bruna 1999; Haila 1999 and 2002; Lindenmayer & Fisher 2006). There is a substantial body of literature studying its effects on the functioning of ecosystems and conservation of diverse flora and fauna at different temporal and spatial scales (e.g. Turner 1996; Harrison & Bruna 1999; Donovan & Flather 2002; Schmiegelow & Mönkkönen 2002; Thompson et al. 2002; Tscharntke et al. 2002; Fahrig 2003; Groom et al. 2005 pp. 213-252). Recently special issues of leading scientific journals have been fully dedicated to the subject (e.g. *Ecological Applications* volume 12 number 2 2002).

Despite the large number of research efforts on forest fragmentation (and actually due to the diversity of their findings) there is still ambiguity on what "fragmentation" is and what its effects are (Villard 2002; Groom et al. 2005; Lindenmayer & Fisher 2006). Several factors contribute to making the concept of fragmentation ambiguous and context dependent (Lord & Norton 1990; Murcia 1995; Haila 1999 and 2002; Harrison & Bruna 1999; McGarigal & Cushman 2002; Villard 2002; Lindenmayer & Fisher 2006) among them: (1) Habitat fragmentation consists of both reduction in the total area of the original habitat and change in the spatial pattern of what remains; (2) different single species, groups of species, and ecological systems experience and respond to the degree of fragmentation of a particular environment in different, even contradictory ways; (3) numerous temporal and spatial scales must be considered, the relevant scales for different single species, group of species, ecosystem processes, geographic regions, and types of environments are likely to be different; (4) ambiguity on whether the focus of work is on either land-cover fragmentation in a landscape (e.g. a specific vegetation type), or on fragmentation of habitat suitable for a particular individual species of plant or animal; (5) lack of focus on the processes and mechanisms underlying and giving rise to the emergent fragmentation patterns; (6) lack of a clear standard for assessing human-caused fragmentation in light of the fact that all natural environments are fragmented to some degree, and they are subject to continuous change due to natural processes; and (7) lack of consistency in study design and methodologies used to analyze habitat fragmentation makes comparisons, integration of information and results, and replication of studies difficult.

Although it is not easy to draw broad general conclusions regarding forest fragmentation, there is general agreement among scientists and forest managers of the need to quantify it and to integrate these estimations into management plans and simulations that will assist us in better understanding the interactions among human activities, forest features, and ecological processes (Murcia 1995; Boutin & Herbert 2002). This interest is reflected in the number of studies dedicated to analyzing the study designs, metrics, and indicators used to estimate the fragmentation of the forests (e.g. Shugart & Smith 1996; Hargis et al. 1998; Debinski & Holt 2000; Santiago and Martinez-Millan 2001; McGarigal & Cushman 2002; Rutledge 2003); and also in the number of standalone programs and tools for Geographic Information Systems (GIS) that have been developed for fragmentation and landscape analysis (see http://rmgsc.cr.usgs.gov/latp/tools.shtml).

There have been efforts to estimate the level of fragmentation of the temperate and tropical forests at the global (e.g. Riitters et al. 2000; Wade et al. 2003) and national levels (e.g. Heilman et al. 2002; Riitters et al. 2004; Kupfer 2006). More common are studies that concentrate on the effects of forest fragmentation on specific plant and animal species at local and regional levels (e.g. Honnay et al. 2002; Schmiegelow & Mönkkönen 2002; Zipkin et al. 2009). In Mexico there have been approximately 41 studies published in the last 10 years on the fragmentation of the forests (search in www.ingentaconnect.com). These studies have concentrated on studying the effects of forest fragmentation on specific flora and fauna species at the local and regional levels (e.g. Estrada & Coates-Estrada 1996 and 2002; Estrada et al. 1999 and 2006; Mas et al. 2000, Ochoa-Gaona 2001, Andersen 2003, Ochoa-Gaona et al. 2004, Cayuela et al. 2006a and 2006b; Galicia et al. 2008; Arroyo-Rodriguez et al. 2009). Fragmentation studies that have had a national coverage, have been limited to specific forest types (e.g. Trejo & Dirzo 2000). There is a need for a consistent nation-wide evaluation of the fragmentation of all the forest types existing in the country, and for an analysis of how forest fragmentation has evolved in time.

Methodology

Data sets.

The National Institute of Statistics, Geography, and Informatics (INEGI) Land Use and Vegetation Cover vector data sets scale 1:250,000 known as Series II (from 1993), and Series III (from 2002) (see INEGI 2005) were used to identify the areas covered by the following forest types (see appendix 1 for details on the

vegetation covers included in each of them). INEGI has revised and made compatible the information from the Series II and Series III (FAO 2010). First, two broad forest types "Temperate Forests" and "Tropical Forests" were identified. For some conservation and management purposes the fragmentation information at these two broad forest types level is not sufficient. Hence, more specific forest types were identified within the Temperate Forests ("Coniferous Forests" and "Broadleaf Forests"), and the Tropical Forests ("Tropical Dry Deciduous Forests", "Tropical Sub-evergreen Forests", and "Tropical Evergreen Forests"). See appendix 1 for the vegetation covers included in each of these more specific forest types.

The INEGI Series II and III are provided as vector data sets in ESRI's (Redlands, California) shapefile format in projection Lambert Conformal Conic datum NAD 83 units meters. These data sets were converted to ESRI's ArcInfo GRID format using the geographic information system ArcGIS 9.2 (ESRI, Redlands California). The cell size was set at 250m × 250m. This cell size represents accurately the size and edges of the forest patches and it is the smallest cell size at which FragStats 3.3 was capable of processing the different national-level forest covers in the computer system we had available. FragStats requires the uploading into memory (RAM) of the whole study area before processing it; hence large study areas represented through small-cell-size rasters require the use of computers with very large RAM capacity (see FragStats 3.3 documentation online for details http://www.umass.edu/landeco/research/fragstats/documents/fragstats_documents.html)

Fragmentation analysis model.

FragStats 3.3 (McGarigal et al. 2002) was used to generate several fragmentation statistics. This software is capable of generating approximately 60 landscape metrics at the patch, class, and landscape level. However, many of them can be highly correlated (Riitters et al. 1995; Apan et al. 2002); hence, it is important to select uncorrelated metrics (Li et al. 2004). Table 1 describes the nine class level (i.e. the forest type) metrics selected in this study. The search distance used in the calculation of the proximity metrics was 50,000 m. The FragStats 3.3. User's Guide (McGarigal et al. 2002) gives a complete definition and explanation of the metrics in Table 1.

Table 1. Acronyms and definitions of FragStats metrics used in this study

Acronym	Metric name (units)	Description
CA	Area coverd by class (hectares)	Area covered by each forest type.
PLAND	Percent of land covered by class (hectares)	Percent of total analysis area covered by each forest type.
NP	Number of patches	Larger number of patch indicates more fragmentation.
LPI	Largest Patch Index (%)	Percent of the total analysis area composed of the largest patch. Smaller values indicate more fragmentation.
AREA_MN	Mean Patch Size Area (hectares)	Average size of patches is expected to decrease with increasing fragmentation.
SHAPE_AM	Area-weighted Mean Shape Index	Mean patch shape complexity weighted by patch area, equals 1 when all patches are circular and increases as patches become non-circular. Larger values indicate more complex shapes.
FRAC_AM	Area-weighted Mean Patch Fractal Dimesion	Patch shape complexity measure, weighted by patch area; FRAC_AM approaches 1 for shapes with simple perimeters, and 2 for complex shapes.
PROX_MN	Mean Proximity Index	Mean proximity index: Average proximity index for all patches in a class. Proximity index is calculated as the sum of the ratio of patch size to nearest neighbour edge-to-edge distance for all patches within a specified search radius. PROX_MN is expected to decrease over time as patches become smaller and more isolated.
ENN_MN	Mean nearest-neighbor distance (meters)	Sum of distances to the nearest neighboring patch of the same type, based on nearest edge-to-edge distance, for each patch of the corresponding patch type, divided by the number of patches of the same type. Larger values indicate more isolation.

Results

Table 2 presents the FragStats statistics calculated for each date and forest type considered in this study. Between 1993 (INEGI's Series II) and 2002 (INEGI's Series III) there have been a reductions in the areas covered by the Temperate and Tropical Forests (891 818 ha and 3 342 656 ha respectively; see CA statistic in table 1). These values are congruent with recent land use change studies which place the rates of deforestation in the period 1976-2000 at 0.25% per year for temperate forests and 0.76% per year for tropical forests (Mas et al. 2004; Velazquez et al. 2005). However, estimates of deforestation in Mexico vary widely from 365 000 to 1.5 million hectares (ha) per year depending on the methodology used, the definition of what constitutes a forest cover, and the total area of the country considered (Mas et al. 2004).

Results for broad forest types

For the Temperate Forests, the reduction on the percent of the country covered by these forests (PLAND of -2.5%) and the reduction on the percent of the country covered by the largest forest patch (LPI of -14.6%) reflect the decrease in the total area of these forests. There has been a 11.9% decrease in the number patches (NP) and a 10.7% increase in the average size of each

patch (AREA_MN). These values by themselves would suggest declining levels of fragmentation from 1993 to 2002. However, the Mean Proximity Index (PROX_MN) has decreased by 17.6%, while the mean nearest-neighbor distance (ENN_MN) has increased by 8.3% pointing to increasing isolation of the remaining forest patches. Finally, the patch shape complexity metrics (SHAPE_AM and FRAC_AM) have decreased by 17.5% and 0.8% respectively indicating a transition to forest patches with simpler shapes (closer to being circular and with simpler edges). Considered together, all these metrics suggest that the land cover transitions between 1993 and 2002 have resulted on fewer larger average size Temperate Forest patches that have simpler shapes and that are more isolated.

Table 2. FragStats fragmentation metrics for the dates and forest types defined in this study

Forest type/Date	CA	% change	PLAND	% change	NP	% change	LPI	% change	AREA_MN	% change
INEGI Series II (1993)										
Temperate Forests	35045281		18.07		10005		7.14		3503	
Coniferous Forests	20900781		10.78		5761		4.1		3628	
Broadleaf Forests	14144500		7.29		10352		0.62		1366	
Tropical Forests	34857419		17.97		7242		5.32		4813	
Tropical Dry Deciduous Forests	22232738		11.46		4242		2.74		5241	
Tropical Sub-evergreen Forests	7984438		4.12		1172		3.33		6813	
Tropical Evergreen Forests	4640244		2.39		2119		0.83		2190	
INEGI Series III (2002)										
Temperate Forests	34153463	-2.5	17.61	-2.5	8811	-11.9	6.1	-14.6	3876	10.7
Coniferous Forests	16782900	-19.7	8.65	-19.7	5216	-9.5	3.01	-26.7	3218	-11.3
Broadleaf Forests	17370563	22.8	8.96	22.8	9301	-10.2	0.94	51.6	1868	36.7
Tropical Forests	31514763	-9.6	16.25	-9.6	9488	31	5.04	-5.2	3322	-31
Tropical Dry Deciduous Forests	21065769	-5.2	10.86	-5.2	6905	62.8	2.14	-21.9	3051	-41.8
Tropical Sub-evergreen Forests	6961775	-12.8	3.59	-12.8	1498	27.8	2.86	-14	4647	-31.8
Tropical Evergreen Forests	3487219	-24.8	1.8	-24.8	1545	-27.1	0.62	-24.8	2257	3.1

Forest type/Date	SHAPE_AM	% change	FRAC_AM	% change	PROX_MN	% change	ENN_MN	% change
INEGI Series II (1993)								
Temperate Forests	28.99		1.25		105677.5		843.95	
Coniferous Forests	25.21		1.24		73378.66		951.09	
Broadleaf Forests	8.25		1.18		3354.66		981.85	
Tropical Forests	31.5		1.26		65065.44		810.92	
Tropical Dry Deciduous Forests	32.71		1.27		62800.13		866.08	
Tropical Sub-evergreen Forests	10.64		1.19		16871.06		996.11	
Tropical Evergreen Forests	11.03		1.2		4169.31		990.65	
INEGI Series III (2002)								
Temperate Forests	23.91	-17.5	1.24	-0.8	87060.11	-17.6	914.26	8.3
Coniferous Forests	20.5	-18.7	1.23	-1.1	38256.73	-47.9	928.29	-2.4
Broadleaf Forests	8.82	6.9	1.18	0.4	5207.72	55.2	1020.13	3.9
Tropical Forests	24.21	-23.1	1.25	-0.9	37626.51	-42.2	753.24	-7.1
Tropical Dry Deciduous Forests	24.46	-25.2	1.25	-1.6	27454.72	-56.3	739.61	-14.6
Tropical Sub-evergreen Forests	17.7	66.4	1.22	2.9	41230.84	144.4	936.64	-6
Tropical Evergreen Forests	10.61	-3.8	1.19	-0.5	3217.81	-22.8	1016.38	2.6

For the Tropical Forests, the PLAND and LPI metrics have both decreased 9.6% and 5.2% respectively. Again this is a reflection of the total reduction on the cover of these forests. The numbers of patches (NP) has increased by 31% while the mean size of each patch (AREA_MN) has decreased by the same proportion. These two values by themselves point to a substantial increase in the fragmentation of these forests. The Mean Proximity Index (PROX_MN) has decreased by 42.2% indicating that the remaining forest patches are becoming smaller and more isolated. However, on the average at the national level, the sum of the distances to the nearest neighboring patch divided by the number of patches (ENN_MN) has decrease of 7.1%. The patch shape complexity metrics (SHAPE_AM and FRAC_AM) have decreased by 23.1%% and 0.9% respectively indicating a transition to more compact forest patches with simpler shapes. Considered together, all of these metrics suggest that the land cover transitions between 1993 and 2002 have resulted on a larger number of smaller average size Tropical Forest patches that have simpler shapes and that are more isolated.

Results for the more specific forest types

Within the Temperate Forests, the Broadleaf Forests have much higher indicators of fragmentation than the Coniferous Forests. In both the Series II and III, they have almost twice the number of patches (e.g. 9,301 reported in the 2002 Series III) than the

Coniferous Forests (5,216 for the same date), their mean patch size (AREA_MN) is almost half of that reported for the Coniferous Forests (e.g. 1 867 ha vs. 3 217 ha according to the Series III), while both type of forests cover comparable areas (17 370 563 ha vs. 16 782 900 ha according the Series III; see column CA in table 2). Also, the metrics of isolation of the forest patches are higher for the Broadleaf Forest than those of the Coniferous Forests (lower PROX_MN values and higher ENN_MN values for the same date). In contrast, the Broadleaf Forest patches have simpler shapes than their Coniferous Forest counterparts (lower SHAPE_AM and FRAC_AM values for the same date). These results most be taken in the context that most Broadleaf Forests are embedded or adjacent to Coniferous Forests. They are composed of mixes of different temperate deciduous broadleaf species, as well as mixes of different proportions of pine (*Pinus spp.*) and oak (*Quercus spp.*) species. The last fact explains why the area reported for these forests is higher in the Series III than in the Series II; pine-oak mixes dominated by oaks are part of the Broadleaf Forests defined in this study.

Within the Tropical Forests, the Tropical Evergreen Forests patches are on the average the smallest (lowest AREA_MN), and have the highest indicators of isolation (lowest values of PROX_MN and highest values of ENN_MN) in both Series II and III. These forests also cover the smallest total surface of all the specific forest types identified in this study (e.g. CA of 3 487 219 ha according to Series III). The forest patch shape complexity metrics (SHAPE_AM and FRAC_AM) are the lowest among the Tropical Forests indicating that these forests are arranged in compact patches with simple edges. In contrast, the Tropical Dry Deciduous Forests have the highest values of patch shape complexity and these values have increased from 1993 to 2002, while the value of mean patch size area is in the middle of the range observed within the Tropical Forests. The patches of these forests are the closest (lowest ENN_MN) and their Mean Proximity Index also points to low levels of isolation. The Tropical Sub-Evergreen Forests are arranged on the average in the largest patches sizes (largest AREA_MN) of all the Tropical Forests; hence the number of patches is small for the total area they cover (e.g. they have almost the same number of patches as the Tropical Evergreen Forests while covering close to twice the total area as these forests). Their patch shape complexity and isolation metrics are in the middle of the range observed for the Tropical Forests.

Discussion

INEGI's Series II and Series III are the most reliable and compatible sources of land cover information available to date at the national level for Mexico (FAO 2010). However, the following issues must be considered when interpreting the results previously presented. First, the land cover source data has a scale of 1:250,000. The generalization effects associated with this scale must be kept in mind (see Muller et al. 1995; Joao 1998; Mackaness & Chaudhry 2008 for a discussion of this topic). Only certain level of detail is possible and classification errors are likely to exist in maps created at this scale. Second, the cell size and its interaction with the scale used have effects on landscape pattern metrics (for details see Turner et al. 1989; O'Neill et al. 1996; Greenberg et al. 2001; Riitters et al. 2002; Corry and Lafortezza 2007). Some fragmentation metrics are robust to changes in cell size (e.g. Total Area CA) while others exhibit erratic responses (e.g. Number of Patches NP). Third, there a limitations and consideration that most be taken into account in the use and interpretation of the FragStats metrics (for details see http://www.umass.edu/landeco/research/fragstats/documents/Conceptual%20Background/Limitations/Limitations.htm).

Despite these considerations, the concept of "fitness for use" (see Joao 2001) applies here. The cell size, scale of the source land cover data, and the pattern metrics used in this study are sufficient and appropriate to characterize and identify trends in the forest fragmentation at the national. This is particularly true for the broad forest types Temperate Forests and Tropical Forests defined in this study. The interpretation of the fragmentation metrics for the more specific forest types (e.g. Broadleaf Forests or Tropical Evergreen Forests) must be done considering the complexities involved in identifying the vegetation covers that were grouped into these forest types, and the spatial relations with other forest covers (e.g. Tropical Dry Deciduous Forests tend to be embedded in a matrix of non-forest land covers, while Broadleaf Forests are generally embedded or adjacent to Coniferous Forests).

Conclusions

Knowing the extent and location of the remaining forest areas is important but not enough to support the formulation of effective forest management, conservation, and restoration plans. The characterization of the spatial pattern of the remaining forests is a fundamental piece of information to develop these plans. The results of this study provide this information that so far has been missing at the national level for all the forest types existing in Mexico. The methodology and results of the metrics here presented provide a basis for a continuous national level monitoring of the evolution of the fragmentation characteristics of the forest areas in the country.

Our study does not distinguish between natural and anthropogenic fragmentation. For some ecosystem functions or species this distinction does not matter. However, we recognize that knowing the causes of the fragmentation patterns in different places and forest types is essential to choose an adequate management or conservation strategy.

The land cover transitions that have occurred in the 1993-2002 period have resulted in more isolated forest patches with simpler shapes in both the Temperate and Tropical forests. The remaining Tropical Forest patches have become smaller and more numerous. In contrast, the remaining Temperate Forest patches are fewer and on average larger.

Of the more specific forest types defined in this study, the Broadleaf Forests have the highest indicators of fragmentation. However, these forests are usually embedded or adjacent to Co-

niferous Forests. Of more concern for conservation and management purposes are the high values of fragmentation metrics found for the Tropical Evergreen Forests which are scarce and usually surrounded by non-forest land covers or anthropogenic land uses. Also of concern are the fragmentation characteristics of the Tropical Dry Deciduous Forests. Although they are comparatively abundant, they have high indicators of fragmentation. This fragmentation could be in part natural to this type of vegetation, but also it has been attributed to extensive anthropogenic disturbances putting this type of forests among the most threatened ecosystem in the world (Portillo-Quintero & Sanchez-Azofeifa 2009) and in Mexico (Trejo & Dirzo 2000).

There are limitations and considerations that must be kept in mind when using available land cover maps to assess the fragmentation of different forest types at the national level in Mexico. Besides the issue of interpreting the fragmentation metrics generated in this study, it is necessary to research the following issues. First, there is a need to incorporate ancillary information such as location of roads and proximity to population centers to better define forest patches and to better evaluate their level of connectivity and levels of anthropogenic pressure on the remaining forests at different scales. Second, there is a need to develop methods to assess the risk of future fragmentation as well as to forecast and simulate future patterns of fragmentation in areas where rapid land use change is occurring. Finally, there is a need to better distinguish natural patterns versus anthropogenic-driven patterns of forest fragmentation because their effects and future consequences are not the same. We have started efforts to address these information needs.

While new studies are conducted, forest spatial pattern cannot not be ignored and national level assessments like the one here presented are a necessary step toward assessing the evolution and possible impacts of forest fragmentation on the sustainability of these ecosystems in Mexico.

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Appendix 1: Vegetation types included in the definition of each forest type.

INEGI's Series II (1993)

The vegetation community information contained in the "Comunidad" attribute field was used to define the following forest types:

Forest type	"Comunidad"
Coniferous forests	'Bosque de tascate' 'Bosque de oyamel (incluye ayarin y cedro)' 'Bosque de pino' 'Bosque de pino-encino (incluye encino-pino)'
Broadleaf forests	'Bosque bajo-abierto' 'Bosque de encino' 'Bosque mesofilo de montana'
Tropical dry deciduous forests	'Selva mediana caducifolia y subcaducifolia' 'Selva baja caducifolia y subcaducifolia' 'Selva baja espinosa'
Tropical sub-evergreen forests	'Selva alta y mediana subperennifolia' 'Selva baja subperennifolia'
Tropical evergreen forests	'Selva alta y mediana perennifolia' 'Selva baja perennifolia'

INEGI's Series III (2002)

The vegetation type information contained in the "TIP_VEG" attribute field was used to define the following forest types:

Forest type	"TIP_VEG"
Coniferous forests	'BOSQUE DE TASCATE' 'BOSQUE DE CEDRO' 'BOSQUE DE AYARIN' 'BOSQUE DE OYAMEL' 'BOSQUE DE PINO' 'MATORRAL DE CONIFERAS' 'BOSQUE DE PINO-ENCINO'
Broadleaf forests	'BOSQUE DE ENCINO' 'BOSQUE MESOFILO DE MONTANA' 'BOSQUE DE ENCINO-PINO'
Tropical dry deciduous forests	'SELVA MEDIANA SUBCADUCIFOLIA' 'SELVA MEDIANA CADUCIFOLIA' 'SELVA BAJA SUBCADUCIFOLIA' 'SELVA BAJA CADUCIFOLIA' 'SELVA BAJA ESPINOSA CADUCIFOLIA'
Tropical sub-evergreen forests	'SELVA ALTA SUBPERENNIFOLIA' 'SELVA MEDIANA SUBPERENNIFOLIA' 'SELVA BAJA SUBPERENNIFOLIA' 'SELVA BAJA ESPINOSA SUBPERENNIFOLIA'
Tropical evergreen forests	'SELVA ALTA PERENNIFOLIA' 'SELVA MEDIANA PERENNIFOLIA' 'SELVA BAJA PERENNIFOLIA'